



# **NASA Construction of Facilities Validation Processes**

## **Total Building Commissioning (TBCx)**



# TBCx Overview



- **Introduction**
- **Definition(s)**
- **Key Attributes**
- **Objectives**
- **Benefits**
- **Costs**
- **Summary**





# TBCx Overview- Introduction

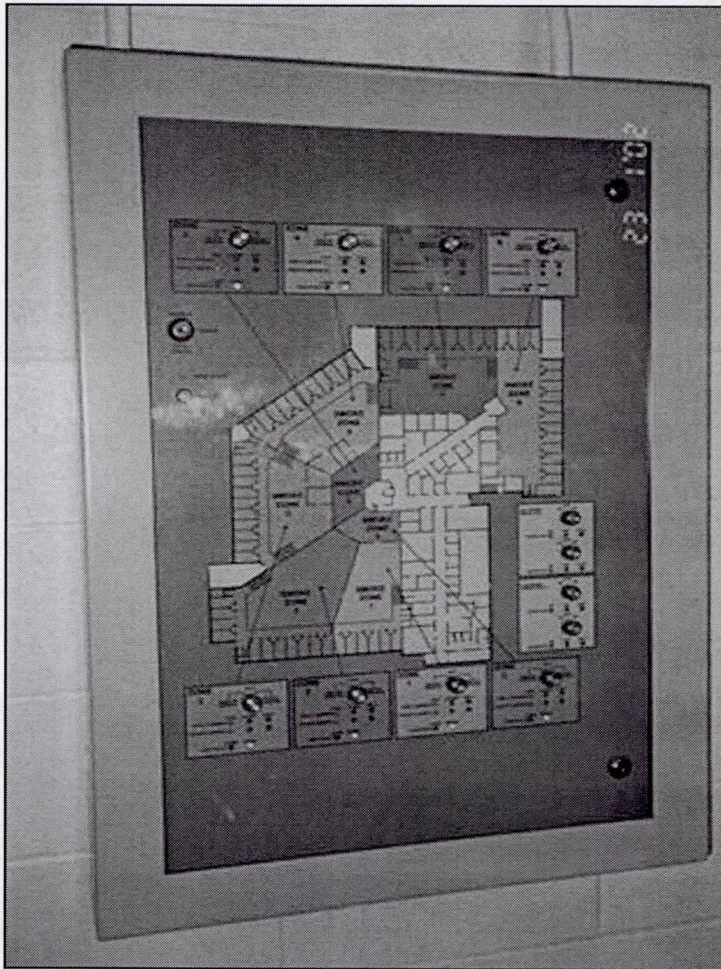


- **“The Problem” with many projects:**
  - **Cost increases after award**
  - **Schedule delays**
  - **Activation and start-up is difficult**
  - **Occupant/User expectations are not met**
  - **Operation and Maintenance (O&M) costs higher than expected**
  - **Desired availability and reliability not realized (Occupant Productivity)**





# TBCx Overview- Introduction



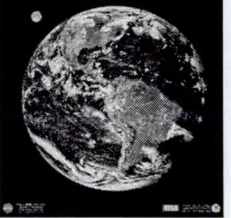
- Multi-Zone Fire Detection & Alarm Control System Panel

- **Building systems technologies are more complex**
- **Facilities are more complicated**
- **Compounded by the interrelationship between systems**





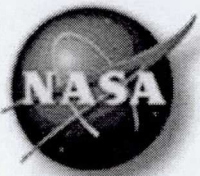
# TBCx Overview- Introduction



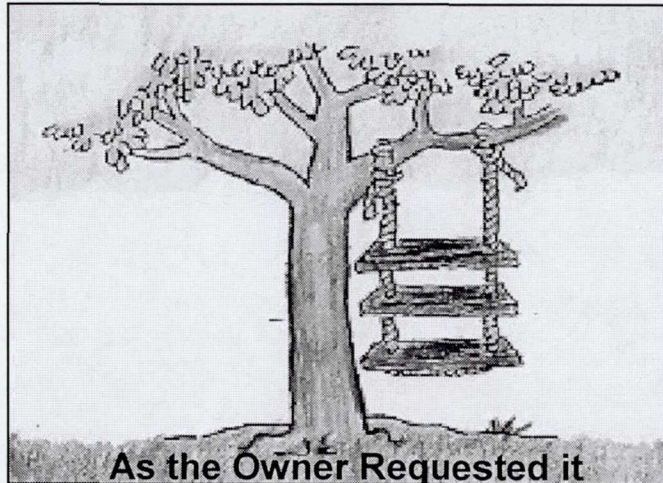
- **A study\* of 60 newly constructed facilities:**
  - **50% suffered from control problems**
  - **40% had Heating, Ventilation, and Air-Conditioning (HVAC) equipment problems**
  - **25% had energy management systems, economizers, and/or variable speed drives that did not function properly**
  - **15% had missing equipment**

\* 1996 Lawrence Berkeley National Laboratory

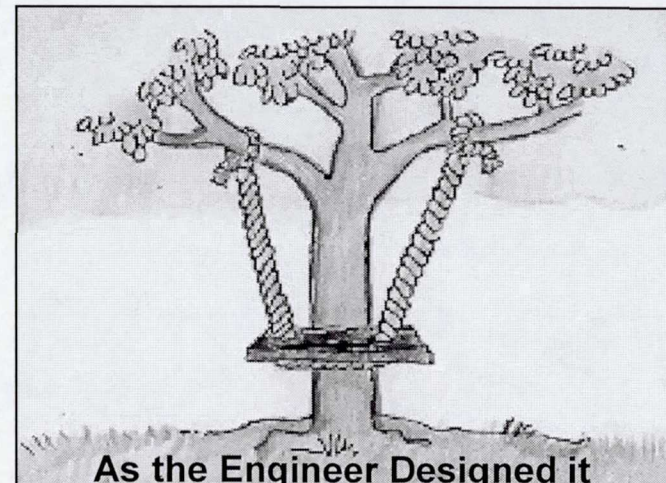




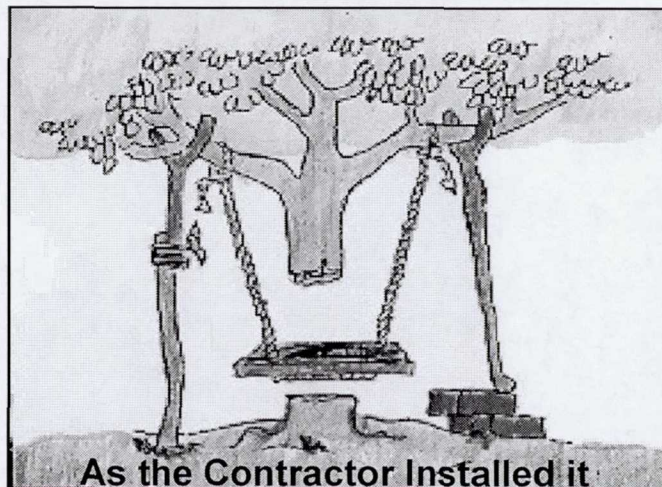
# TBCx Overview- Introduction



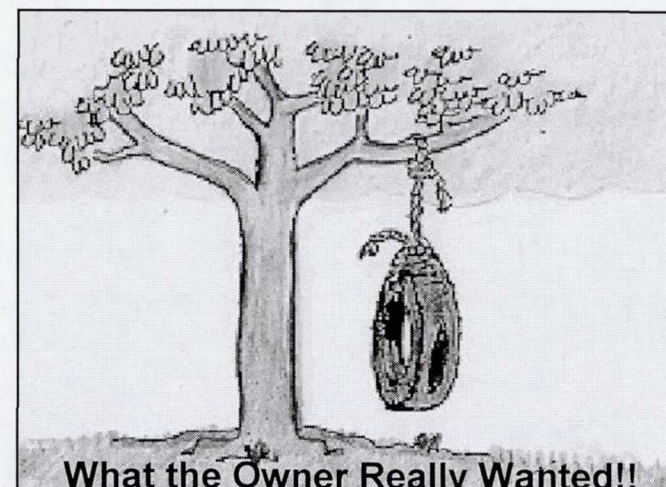
**As the Owner Requested it**



**As the Engineer Designed it**



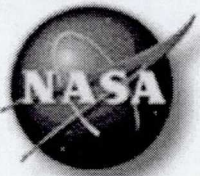
**As the Contractor Installed it**



**What the Owner Really Wanted!!**

- Kentucky Transportation Cabinet, Construction Division, Construction Conference, Lake Cumberland State Park, March 20, 2002





## TBCx Overview- Introduction



- **As a means to better integrate the programming, design, construction and operation of all facilities in general, and in support of Executive Order 13123, NASA has adopted the Total Building Commissioning Process as a Best Practice**



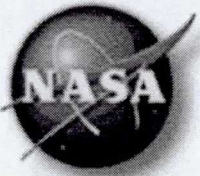


# TBCx Overview- Introduction



- **Total Building Commissioning Process as a Best Practice:**
  - **National Institute of Building Sciences (NIBS) The Total Building Commissioning Process Guideline 0P-200X Working Draft**
  - **ASHRAE Guideline 0P The Commissioning Process 200X Working Draft**
  - **Building Commissioning Association (BCA)**
  - **Operational Readiness Inspection Readiness Criteria for Facilities and Test Activities Handbook NASA STD. 8719.1 Working Draft**





# TBCx Overview – Definition(s)



- **Building Commissioning:**

**“A quality process emphasizing procedures to ensure that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the owners project requirements. The process begins during project planning and extends through design, construction, activation, and operations and maintenance.”\***

**\* NPG 8820.2e**





## TBCx Overview – Definition(s)



- **Total Building Commissioning:**

The process of building commissioning applied to a wide variety of building systems, including but not limited to, structural, building envelope, thermal and moisture protection, doors, windows, equipment, special construction, conveying, mechanical, and electrical systems

- **Continuous Commissioning:**

The application of the commissioning process for the ongoing operation of the facility.





# **TBCx Overview**

## **What TBCx is NOT!**



<ul style="list-style-type: none"><li>• <b>Construction Quality Control:</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Commissioning:</b></li></ul>
<ul style="list-style-type: none"><li>• <b>Materials and workmanship</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Performance and operation</b></li></ul>
<ul style="list-style-type: none"><li>• <b>Quality Assurance to Construction Documents</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Quality assurance to Design Criteria</b></li></ul>
<ul style="list-style-type: none"><li>• <b>Prerequisite to start-up</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Functional testing</b></li></ul>





# **TBCx Overview**

## **What TBCx is NOT!**



<b>• Start-Up:</b>	<b>• Commissioning:</b>
<ul style="list-style-type: none"><li>• Equipment-oriented</li></ul>	<ul style="list-style-type: none"><li>• System-oriented</li></ul>
<ul style="list-style-type: none"><li>• Construction phase activity only</li></ul>	<ul style="list-style-type: none"><li>• Focus on whole life of facility</li></ul>
<ul style="list-style-type: none"><li>• Performed by a equipment specialist with knowledge of the equipment being started</li></ul>	<ul style="list-style-type: none"><li>• Performed by a specialist with knowledge of the various systems' interactions</li></ul>





# **TBCx Overview**

## **What TBCx is NOT!**



- **Testing, Adjusting & Balancing (TAB):**

- **Concerned with:**

- Flow rate
- Pressure
- Temperature

- **Maximum and minimum conditions only**

- **Prerequisite to functional performance testing**

- **Commissioning:**

- **Concerned with:**

- Sequence of operation
- Optimization
- Interrelationships

- **Full range of conditions and loads**

- **Verifies TAB report**





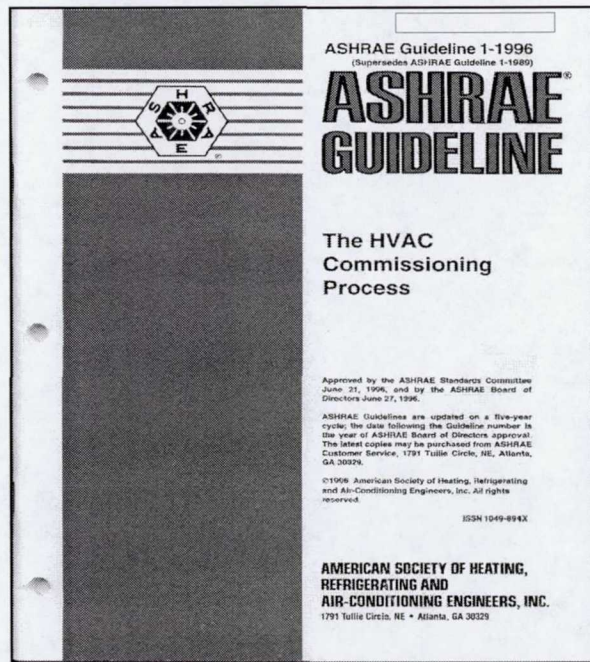
# TBCx Overview

## What TBCx is NOT!



- **ASHRAE:**

- **Concerned HVAC Systems and controls**



\*ASHRAE Guide Line 1

- **Commissioning:**

- **Structural Systems - ASCE**
- **Envelope Systems - BETEC**
- **Roofing Systems - NRCA**
- **Interior Systems - AWC**
- **Elevator Systems - NEII**
- **Plumbing Systems - ASPE**
- **Lighting Systems - IES**
- **Electrical Systems - IEEE**
- **Fire Protection Sys - NFPA**
- **Telecommunication Sys. - TIA**





## **TBCx Overview - Key Attributes**



- **A Total Quality Management (TQM) System that looks at all phases of a project**
- **A team process that spans boundaries**
- **A Commissioning Authority to lead the process**
- **Commissioning requirements in contracts**



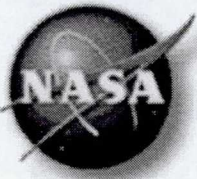


## **TBCx Overview - Key Attributes Continued**



- **Independent design review to verify compliance with Facility Project Requirements (FPR)**
- **Formal written Commissioning Plan with Documented Results**
- **Functional performance testing (FPT) against the requirements document**





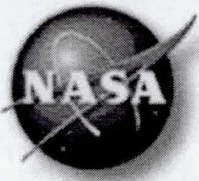
# **TBCx Overview - Key Attributes**

## **A Quality Process**



- **Establish quality goals and tools for all aspects of the work, in all phases of the facility development**
- **A Quality process that stresses defect prevention versus inspection rejection**
  - **Involvement at the start of activities to achieve the desired results thus minimizing defects in the finished work**





## **TBCx Overview - Key Attributes**

### **Engage a TBCx Authority**



- **The Commissioning Team Leader**
- **The Advocate for Functional Quality**
- **Makes Final Recommendations Regarding Functional Performance of Systems**





# **TBCx Overview - Key Attributes**

## **A Team Process**



- **Commissioning Authority (CA)**
- **Architect & Engineer (A/E)**
- **Contractors & Suppliers**
- **NASA**
  - **User Representative**
  - **Facility Project Manager**
  - **Sustainability Champion**
  - **Energy Rep.**
  - **Safety Rep.**
  - **Security Rep.**
  - **Environmental Rep.**
  - **O&M Rep.**
  - **O&M Contractor**
  - **Construction Mgt.**





# **TBCx Overview - Key Attributes Review Design**



- **Independent design review to verify compliance with FPR:**
  - **Maintainability - safe, accessible, & efficient**
  - **Operability - safe, accessible, & efficient**
  - **Reliability:**
    - RCB&EA criteria
    - PT&I requirements
  - **Coordination of Design Discipline & Systems**
  - **Ability to perform as required at all loads, under all operating conditions**





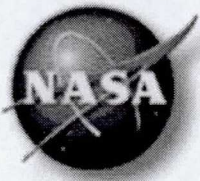
# **TBCx Overview - Key Attributes**

## **Use a TBCx Plan**



- **Communication tool, not contractual**
- **Guides commissioning process**
- **Defines scope of commissioning**
- **Defines roles of commissioning team**
- **Outlines the organization, schedule, allocation of resources, and documentation requirements of the Commissioning Process**



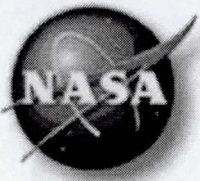


# **TBCx Overview - Key Attributes Testing**



- **Contractor involvement**
- **Multiple levels**
  - **components, equipment, subsystem, systems and intersystem**
- **Quality involvement in all levels of testing**
  - **Written repeatable procedures, Measurable criteria, & Validated results**





# **TBCx Overview - Key Attributes Written Reports**



- **Reviews**
- **Site Observations**
- **Test Data & Recommendations**
- **Deficiencies and Corrective Actions**
- **Final Report & Recommendations**





# TBCx Overview - Objectives



- **Achievement of Facility Project Requirements (FPR):**
  - **User functionality and special needs**
  - **Degree of compliance with codes and regulation**
  - **Building context and function**
  - **Safety and security goals**
  - **Maintainability and operability design goals**





# TBCx Overview - Objectives



- **Achievement of Facility Project Requirements (FPR) Continued:**
  - Predictive Test and Inspection (PT&I) goals
  - Indoor Environmental Quality (IEQ) and health/comfort goals
  - Sustainable design goals
  - Budget and schedule goals





# TBCx Overview - Objectives



- **Quality Verification and Document:**
  - That equipment and systems are designed, installed and perform per FPR
  - Proper operation under normal and emergency situations
  - Proper operation under all loads
  - Sustainable design features perform





## **TBCx Overview - Benefits**



- **A Quality Management System:**
  - **Identifies & resolve functional issues early**
  - **Optimize reliability & performance**
  - **Coordination between Design Disciplines and among systems & assemblies**
  - **Provides knowledge transfer and training to O&M Staff**
  - **Promotes a safe, healthy, secure, comfortable and reliable facility**
  - **Achieves project goals & intended performance**





# TBCx Overview - Benefits



- **Indirect Improvements:**

- **Reduced Occupant Complaints**

- **Occupant Productivity \***

- **Standard Office Building                      250K Sq. Ft.**

- 1,500 Occupants -\$40K Average Salary \*\***

- \$60M Annual Occupancy Total Salary**

- \$60M X 1.3 = \$78M w/Fringe Benefits**

- \$78M/2086 = \$37k/hr production cost**

- **10%-20% Changes in Productivity + or -**

- \$8M - \$16M each year every year**

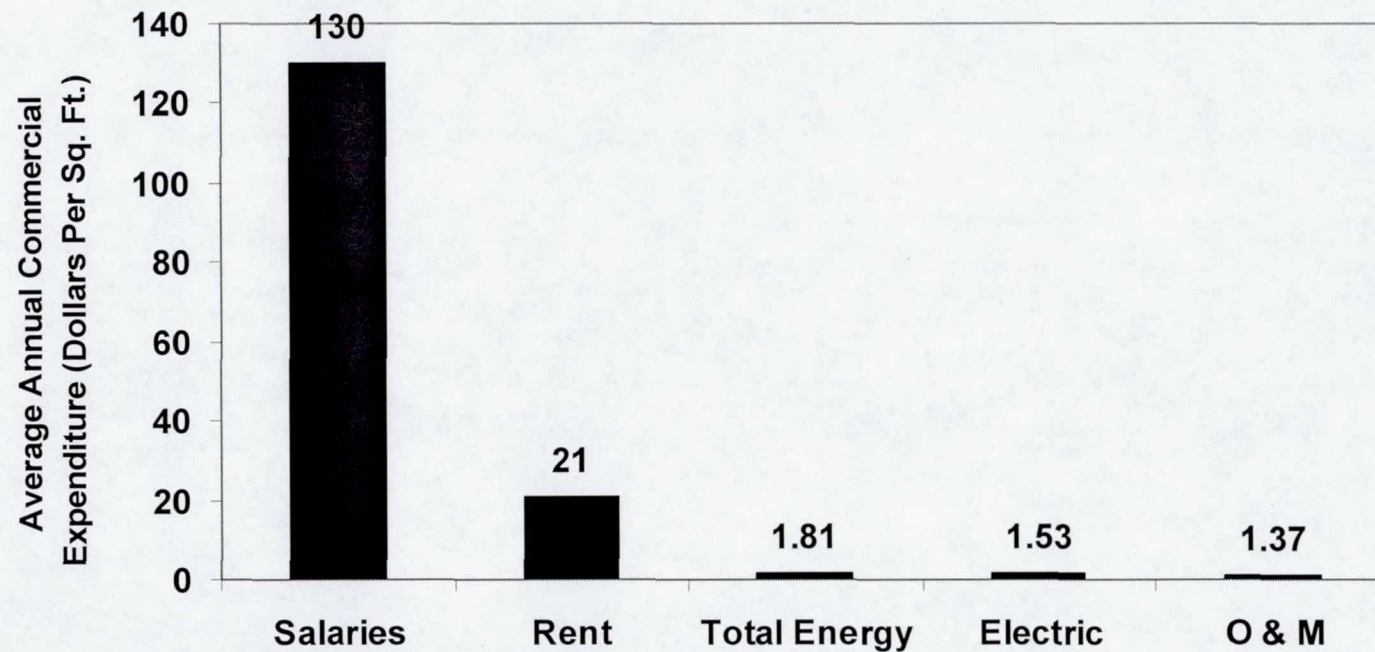
**\* Modified from PECl**

**\*\* US Census Bureau**





# TBCx Overview – Benefits Productivity



Data from Building Owners and Manager Association  
Electric Power Research Institute;  
Statistical Abstract of the United States 1991





# TBCx Overview - Benefits

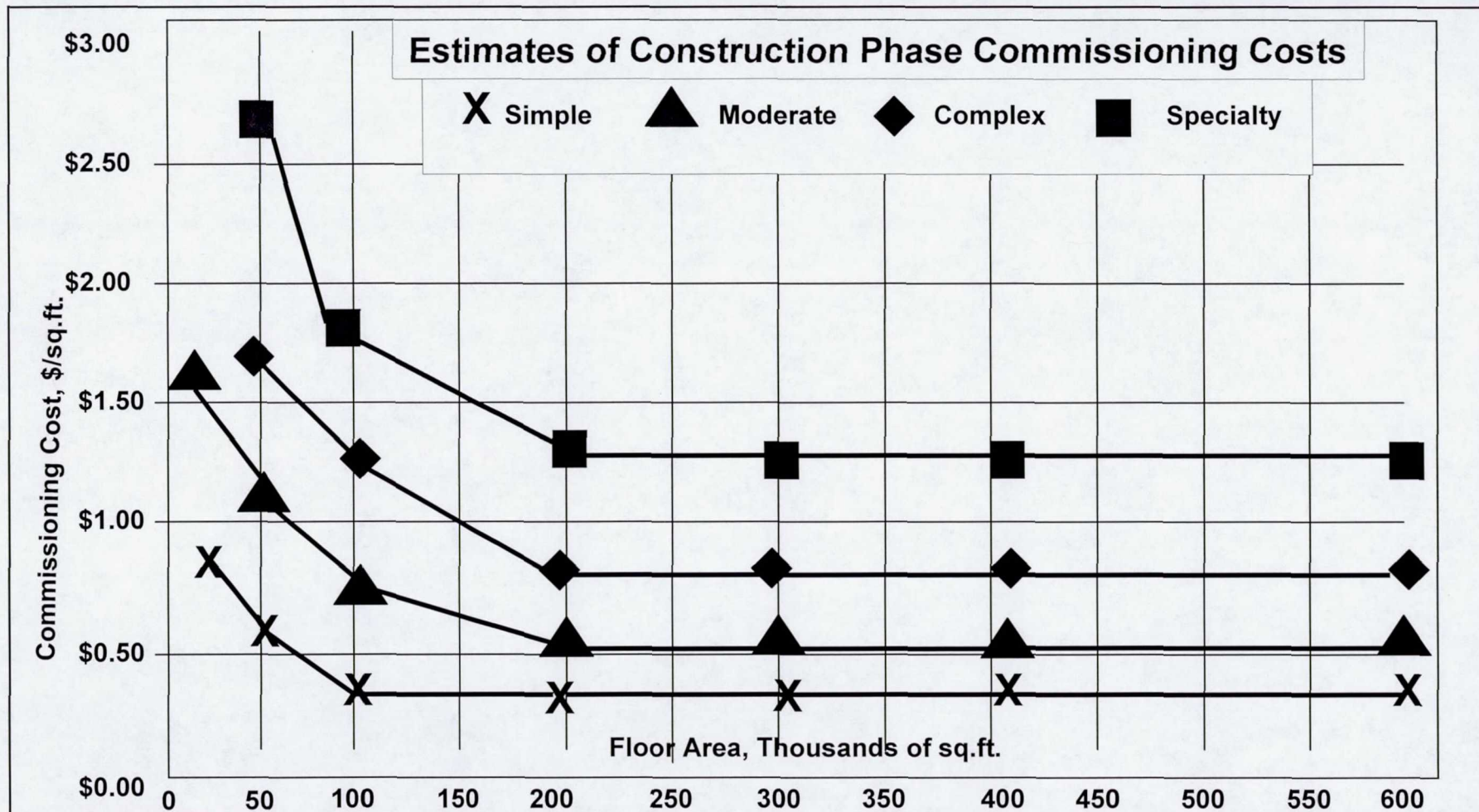


- **Factors that impact benefits:**
  - **How early in the process TBCx starts**
  - **Commitment**
  - **Team organization & composition**
  - **Cooperation of Team Members**





# TBCx Overview – Cost



Portland Energy Conservation, Inc 2000

Building Commissioning Guidelines for New Construction: Project Manager's Perspective.



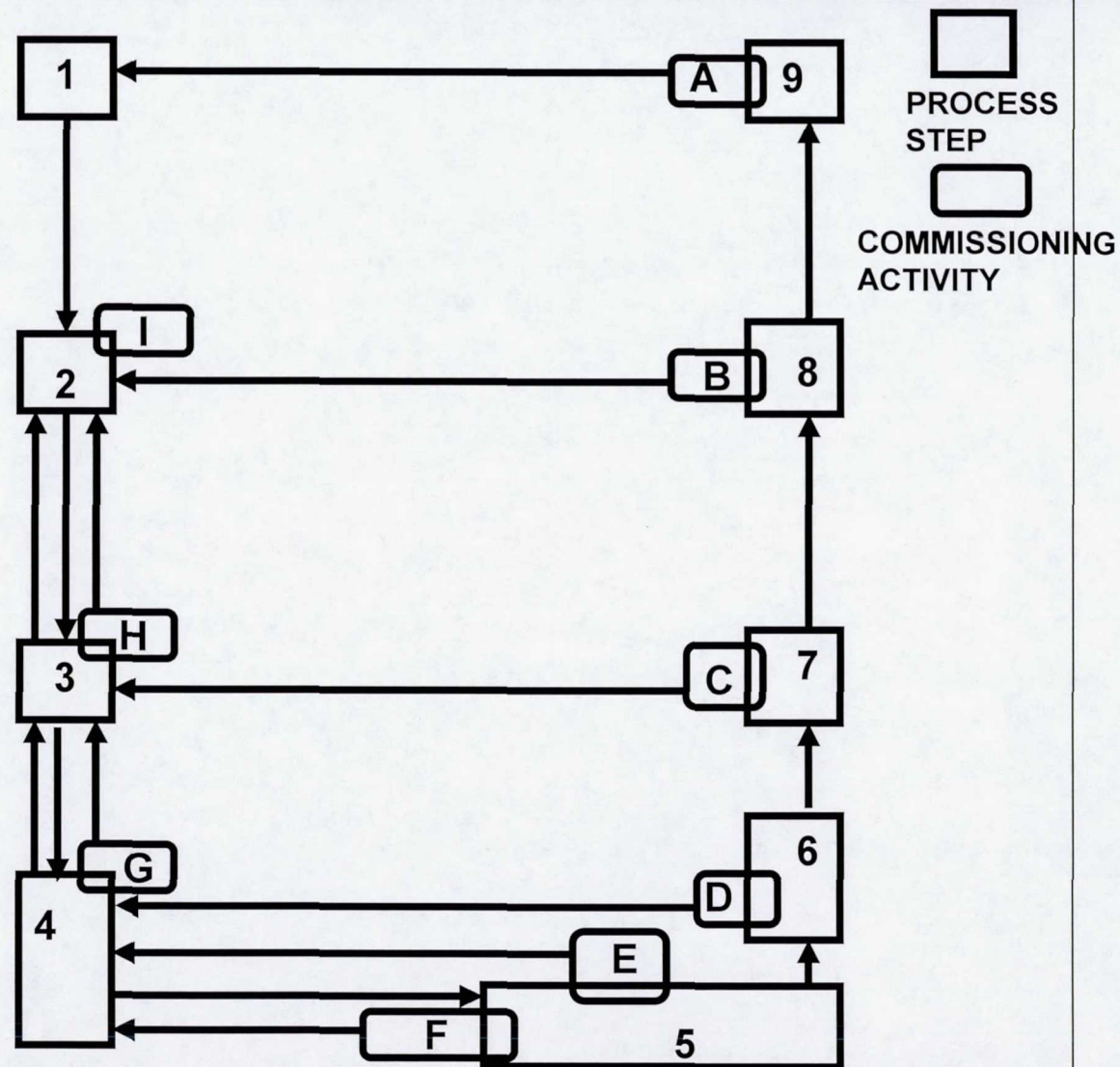


# TBCx Overview - Summary



1. User Needs
2. Planning
3. Design
4. Construction Documents
5. Construction
6. Acceptance
7. Startup
8. Activation
9. Occupy

- A. User Validation
- B. Performance Validation
- C. Functional Validation
- D. Field QC Validation
- E. Source QC Validation
- F. Change Validation
- G. CD Validation
- H. Design Validation
- I. Commission Plan







# **TBCx Overview - Summary LEED Requirements**



- **Commissioning Summary:**
  - **Prerequisite 1: Verify and ensure that fundamental building elements and systems are designed, installed and calibrated to operate as intended.**
    - Engage a commissioning authority.
    - Develop owner's performance requirements for energy, water and IEQ and review the basis of design to verify performance requirements have been met.
    - Incorporate commissioning requirements into the construction documents.
    - Develop and utilize a commissioning plan.
    - Verify installation, functional performance, training and operation and maintenance documentation.
    - Complete a commissioning report.





# **TBCx Overview - Summary LEED Requirements**



- **Commissioning Summary Continued:**

- **Energy Credit #3: Verify and ensure that the entire building is designed, installed and calibrated to operate as intended.**
  - A CA independent of the design team shall conduct a focused review of the design....
  - The independent CA shall conduct a focused review of the construction documents...
  - The independent CA shall review the contractor submittals relative to systems being commissioned.
  - Provide information to the owner in a single document (manual) that is required for re-commissioning building systems.
  - Have a contract in place to review building operation ... within one year after construction completion date.





# **TBCx Overview - Summary LEED Requirements**



## **Commissioning Summary Continued**

- **Energy Credit #5: Provide for the ongoing accountability and optimization of building energy and water consumption performance over time:**
  - **Install continuous metering equipment for end-uses.**
  - **Develop a Measurement and Verification plan that incorporates the monitoring information from the above end-uses.**